MACHINE TRANSLATION FOR JP 07-157824

* NOTICES *
JPO and INPIT are not responsible for any
damages caused by the use of this translation.
1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]
[Industrial Application] This invention relates to the manufacture approach of the sub-hot forged microalloyed steel which can give the outstanding tensile strength, yield strength, toughness, a fatigue property, machinability, and yield strength to coincidence in more detail about the manufacture approach of machine structural steel worker components including the object for automobiles by sub-hot forging by performing aging treatment to specific steel after sub-hot forging.

[0002]
[Description of the Prior Art] Application of non-heat-treated steel has spread from a viewpoint of a process abbreviation and reduction of a manufacturing cost to machine structural steel worker components including an automobile.

[0003] Development has been performed for the purpose of these non-heat-treated steel having mainly high tensile strength (or hardness) and mainly high toughness. The non-heat-treated steel using V which is the typical element of precipitation strengthening has been proposed so that JP,62-205245,A etc. may see there. However, on the occasion of application to the machine part of the non-heat-treated steel of such high intensity quantity toughness, degradation of the cutting ability accompanying the increment in strong has been a serious failure.

[0004] The outstanding machinability is required of a machine part. On the other hand, the most important property also as a machine part is fatigue strength. If it is supposed that it is generally dependent on tensile strength of fatigue strength and tensile strength is made high, it will become high. However, by raising tensile strength, cutting ability deteriorates extremely and tensile strength is 2 120 kgf(s)/mm. If it exceeds, in the usual production efficiency, production will already become impossible. Then, it was anxious for the embodiment of the non-heat-treated steel which raises fatigue strength, without degrading cutting ability.

[0005] It is a means with effective in this raising, the ratio, i.e., the durable ratio, of fatigue strength and tensile strength. The method of considering as a bainite subject's metal texture and

reducing the high carbon island-shape martensite and retained austenite under organization etc. has been proposed so that JP,4-176842,A etc. may see there.

[0006] However, in spite of such development efforts, a durable ratio is about at most 0.55, and is not improved by at most about 2 times of the bainite non-heat-treated steel of a conventional type with very faulty cutting ability. Moreover, in this type of non-heat-treated steel, it became a problem that yield strength is low, and use was not completed with the components by which big stress is applied locally. Furthermore, since toughness was inferior a little compared with temper material, also when higher toughness was required, it was not able to apply.

[0007]
[Problem(s) to be Solved by the Invention] This invention offers the manufacture approach of sub-hot forged microalloyed steel that implementation has yield strength and toughness in coincidence further in addition to difficult high durable ratio and cutting ability, by the manufacture approach of conventional hot-forging mold non-heat-treated steel, i.e., natural radiationnal cooling after hot forging.

[0008]
[Means for Solving the Problem] this invention persons found out that cutting ability became very good, when this recognized suitable amount existence all over the metal texture first paying attention to the pearlite organization. However, if the pearlite ratio of organized labor which is an elevated-temperature transformation organization generally becomes high, a yield ratio, a durable ratio, and toughness will deteriorate.

[0009] Then, it worked on the policy which makes high a yield ratio, a durable ratio, and toughness to the pearlite mixing organization steel with which cutting ability becomes very good. Consequently, consider as the steel presentation which adjusted C and V addition, and make detailed austenite crystal grain at the time of forging heating with **TiN and a MnS-V(CN) compound sludge. ** Forging finishing temperature performs sub-hot forging on the conditions which are 750-900 degrees C, and makes austenite crystal grain detailed further with processing recrystallization. ** ** which carries out the detailed deposit of the ferrite from the inside of the grain of an austenite grain by the cooling process by making the above-mentioned MnS-V(CN) compound sludge into a karyogenesis site -- by subsequently performing aging treatment after forging radiationnal cooling By performing the above warm working and the aging treatment after forging radiationnal cooling to which deposit V carbide or V carbon nitride on the ferrite matrix background in a ferrite and a pearlite very minutely further, and it is made to carry out precipitation strengthening of the matrix Yield strength has been improved notably, toughness also improved to coincidence, and it found out that fatigue strength and cutting ability were also excellent.

[0010] this invention persons perform the chemical entity of the steel for hot forging containing a pearlite, and a design of a metal texture based on such knowledge, and are sub-hot forging about this ingredient further. - The conditions which carry out aging treatment are examined and it came to invent this invention.

[0011] The 1st invention of this invention is made into a weight ratio. Namely, C:0.15 - 0.50%, Si: 0.005-2.00%, Mn:0.40-2.00%, S:0.01 - 0.10%, aluminum: 0.0005-0.050%, Ti:0.003-0.050%, Contain N:0.0020 - 0.0200%, and V:0.20 - 0.70%, and the remainder heats the steel of the presentation which consists of Fe and an impurity element to the temperature of three or more Ac(s). It is made for 90% or more of the metal texture after forging finishing temperature performs sub-hot forging, and makes it cool on the conditions which are 750-900 degrees C and a transformation is completed to be a ferrite + pearlite organization. The yield strength characterized by performing aging treatment to this at the temperature of further 200-700 degrees C, It is the manufacture approach of sub-hot forged microalloyed steel of excelling in toughness and a fatigue property. Further the 2nd invention for the steel component of the 1st invention for adjustment of a ferrite + pearlite ratio of organized labor Cr:0.02-1.50%, One sort of Mo:0.02 - 1.00%** or two sorts are made to contain. The 3rd invention makes the steel component of the 1st invention or the 2nd invention contain Nb:0.001-0.20% further for grain refining. The 4th invention makes the steel component of the 1-3rd invention contain 1 of Pb:0.05-0.30% and calcium:0.0005-0.010% of sorts, and two sorts or more further for the further improvement in cutting ability.
[0012] Next, it is sub-hot forging about a metal texture and this ingredient after performing the steel-materials chemical entity in the manufacture approach of the sub-hot forging components of this invention, and sub-hot forging, cooling and metamorphosing. - The reason for limitation of the conditions which carry out aging treatment is explained below.

[0013] C: A ferrite + pearlite ratio of organized labor is controlled, and carbide or carbon nitride with V is formed during aging treatment, and since it is an element important for making the tensile strength of a final product, yield strength, and fatigue strength increase, and the effectiveness is small at less than 0.15%, hardness becomes high too much by excess 0.50% conversely and toughness and cutting ability are checked, it may be 0.15 - 0.50%.

[0014] Si: By the element which suppresses deoxidation and a deposit of bainite and adjusts a ferrite + pearlite ratio of organized labor, at less than 0.005%, the effectiveness is small, and since both a yield ratio toughness a durable ratio and cutting ability fall by excess 2.00%, it may be 0.005 - 2.00%.

[0015] Mn: By the element which serves as a base of the compound sludge which is the deposit site of a ferrite by being set to MnS while bringing about the increment in the amount of pearlites, and the fall of the temperature of transformation, at less than 0.40%, the effectiveness is small, and since bainite is generated in excess 2.00% and both a yield ratio a durable ratio and cutting ability fall, it may be 0.40 - 2.00%.

[0016] S: By the element which serves as a base of the compound sludge which is the deposit site of a ferrite by being set to MnS, and raises machinability, at less than 0.01%, the effectiveness is small, and since toughness and a durable ratio fall by excess 0.10%, it may be 0.01 - 0.10%.

[0017] aluminum: Since the effectiveness is small at less than 0.0005%, hard inclusion is formed by excess 0.050% and both toughness a durable ratio and cutting ability fall by the element with

the deoxidation effectiveness, it may be 0.0005 - 0.050%.

[0018] Since the effectiveness is small at less than 0.003%, formation of big and rough hard inclusion is urged by excess 0.050% and both toughness a durable ratio and cutting ability fall by the element which forms on Ti:MnS the compound sludge which turns into a nitride, deposits and serves as a deposit site of a ferrite, it may be 0.003 - 0.050%.

[0019] N: although the effectiveness is small at less than 0.0020%, and it considers as 0.0020 - 0.0200% by the element which forms Ti and V, a nitride, or carbon nitride since both toughness a durable ratio and cutting ability fall by excess 0.0200% -- the excess of N -- if -- bad influences, such as formation of a big and rough nitride and matrix hardening, are large, and 0.0070% or less is desirable.

[0020] By the important element which carries out precipitation strengthening of the ferrite in a pearlite, and forms carbide or carbon nitride by aging treatment further while forming V:MnS and TiN, and a compound sludge, at less than 0.20%, the effectiveness is small, and since both toughness a durable ratio cutting ability and a yield ratio fall by excess 0.70%, it may be 0.20 - 0.70%.

[0021] The above is the reason for limitation of the chemical entity of the steel of the 1st invention of this application.

[0022] Next, the steel component of the 1st invention steel is made to contain one sort of Cr and Mo, or two sorts further in the 2nd invention of this application for adjustment of a ferrite + pearlite ratio of organized labor. The reason for limitation of these chemical entities is explained below.

[0023] Almost like Cr:Mn, by the element which brings about the increment in the amount of pearlites, and the fall of the temperature of transformation, at less than 0.02%, the effectiveness is small, and since bainite is generated in excess 1.50% and both a yield ratio a durable ratio and cutting ability fall, it may be 0.02 - 1.50%.

[0024] By the element with Mo:Mn and the almost same effectiveness as Cr, at less than 0.02%, the effectiveness is small, and since bainite is generated in excess 1.00% and both a yield ratio a durable ratio and cutting ability fall, it may be 0.02 - 1.00%.

[0025] The steel component of the 1st invention or the 2nd invention steel is made to contain Nb further in the 3rd invention of this application for grain refining. The reason for limitation of Nb is as follows.

[0026] By the element with the almost same effectiveness as Nb:Ti and V, at less than 0.001%, the effectiveness is small, and since both toughness a durable ratio and cutting ability fall by excess 0.20%, it may be 0.001 - 0.20%.

[0027] The steel component of the 1-3rd invention steel is made to contain one sort of Pb and calcium, or two sorts further in the 4th invention of this application for the further improvement

in cutting ability. The reason for limitation of these chemical entities is explained below.

[0028] Pb: -- since the effectiveness is small at less than 0.05%, the effectiveness is saturated with excess 0.30% and toughness and a durable ratio fall by the element which makes cutting ability improve -- 0.05 - 0.30% -- ** -- it carries out.

[0029] since the effectiveness is small, the effectiveness is saturated with an element with the almost same effectiveness as calcium:Pb and toughness and a durable ratio fall by excess of 0.010% at less than 0.0005% with it -- 0.0005 - 0.010% -- ** -- it carries out.

[0030] In carrying out sub-hot forging of the steel which has these chemical entities, whenever [stoving temperature] shall be made into the temperature of three or more Ac(s), and shall perform hot working in an austenite single phase field. This is for problems, such as a forging crack, to also produce deformability low while the life of the tool which the deformation resistance of steel materials becomes high and uses for forging except an austenite single phase field falls extremely.

[0031] Next, in this invention, the reason which limited forging finishing temperature to 750-900 degrees C is explained. First, the minimum of forging finishing temperature was made into 750 degrees C or more, because a forging load increased notably at the temperature of this less than 750 degrees C and molding became difficult. Moreover, the upper limit of forging finishing temperature was made into 900 degrees C or less because the forging finishing temperature of 900-degree-C ** of the detailed-ized effectiveness of the austenite crystal grain by processing recrystallization was inadequate.

[0032] Next, although it is a metal texture at the time of cooling after sub-hot forging in the steel of the invention in this application, and a transformation being completed, in order to attain the improvement in cutting ability, and improvement in fatigue strength, it is required for 90% or more of a metal texture to be a ferrite + pearlite organization. This effectiveness is not barred even if there are less than 10% of a low-temperature transformation organization or retained austenites, such as bainite, with a ratio of organized labor.

[0033] Although especially the cooling approach after sub-hot forging will not be specified if such a ferrite + pearlite 2 phase organization can be obtained, naturally a facility and natural radiationnal cooling from the point of a manufacturing cost are desirable. In addition, a metal texture checks by the approach of measuring the microhardness of the organization with observing the corroded test piece with an optical microscope etc., and a micro Vickers hardness measurement machine.

[0034] The reason for limitation of the conditions which carry out aging treatment of such an ingredient to the last is explained. At less than 200 degrees C, diffusion of C is difficult for whenever [stoving temperature / of aging treatment], and it becomes inadequate [effectiveness]. Tensile strength not only falls, but the carbide which deposited on the other hand when it exceeded 700 degrees C makes it big and rough, and yield strength and fatigue strength fall. Then, whenever [stoving temperature / of aging treatment] is made into 200-700 degrees C. Although it is not necessary to limit it especially if heating time is this temperature requirement,

it should consider as 10 minutes - about 2 hours desirably. further -- the cooling approach after aging treatment -- air cooling, water cooling, and oil quenching -- the engine performance of this invention can be obtained also by the approach [how].

[0035] Below, an example shows the effectiveness of this invention still more concretely.

[0036]
[Example] In each next table, No. which attached the parenthesis of a divisional column is an example with which are satisfied of this invention, and is an example of a comparison except it.

[0037] a. Once having dissolved the steel of the chemical entity shown in the effect table 1 of a steel-materials chemical entity with the high-frequency furnace, having considered as the 150kg steel ingot, having, started the charge of forging material from now on and carrying out normalizing by 950-degree-C heating radiationnal cooling, it heated at 1050 degrees C, and on the conditions of 850 degrees C of finishing temperature, sub-hot forging was performed and it cooled radiationally after that. Furthermore this ingredient was inserted in the heating furnace with a temperature of 400 degrees C for 1 hour, and aging treatment was performed. From the center section of this ingredient, the JIS No. 4 test piece for tensile test, the JIS No. 3 impact test specimen, and the JIS No. 1 rotation test piece for bend test were extracted, and the tension test, the Charpy impact test (20 degrees C), and the rotation bending fatigue test were performed. The total punching distance until it extracts a cutting test piece, it punches the blind hole of 30mm depth using 10mmphi parallel shank drill made from SKH9 and a drill carries out life destruction more furthermore than this ingredient estimated cutting ability. In addition, cutting speed was made into 50 m/min and the feed rate was made into the conditions of 0.35 mm/rev and cutting oil 3 L/min. Moreover, the optical microscope observation test piece was extracted from the ingredient before aging treatment, and it corroded in NAITARU 5%, and observed by 200 times.

[0038]
[Table 1]

表1（その1）

No.		C	Si	Mn	S	Al	Ti	N	Cr	Mo	Nb	Pb	Ca	V
(1)	第1発明例	0.19	0.813	1.62	0.072	0.0410	0.009	0.0062						0.44
(2)	〃	0.26	0.031	1.71	0.051	0.0266	0.011	0.0031						0.39
(3)	〃	0.28	1.221	1.35	0.046	0.0294	0.043	0.0089						0.34
(4)	〃	0.35	0.242	1.31	0.039	0.0161	0.022	0.0124						0.41
(5)	〃	0.46	0.751	0.55	0.087	0.0232	0.015	0.0181						0.24
(6)	第2発明例	0.32	0.907	0.81	0.044	0.0375	0.026	0.0112	0.50					0.29
(7)	〃	0.22	1.132	0.98	0.059	0.0318	0.013	0.0131		0.28				0.49
(8)	〃	0.27	0.605	1.22	0.063	0.0284	0.017	0.0147	0.44	0.16				0.44
(9)	第3発明例	0.44	0.824	0.43	0.040	0.0249	0.007	0.0153			0.028			0.21
(10)	〃	0.35	1.011	0.95	0.025	0.0313	0.011	0.0048		0.08	0.121			0.27
(11)	〃	0.26	0.420	1.02	0.034	0.0269	0.023	0.0105	0.38	0.10	0.073			0.26
(12)	第4発明例	0.35	0.318	0.72	0.016	0.0321	0.022	0.0142				0.24		0.39
(13)	〃	0.32	0.532	0.84	0.039	0.0009	0.016	0.0111					0.0082	0.38
(14)	〃	0.25	0.742	1.30	0.052	0.0016	0.032	0.0167				0.05	0.0021	0.35
(15)	〃	0.34	1.221	0.61	0.049	0.0253	0.015	0.0056	1.21			0.13		0.36
(16)	〃	0.43	0.316	0.77	0.037	0.0032	0.032	0.0191		0.13		0.11	0.0008	0.33
(17)	〃	0.29	0.718	1.19	0.028	0.0331	0.014	0.0039			0.019	0.27		0.29
(18)	〃	0.42	0.927	0.65	0.064	0.0011	0.044	0.0139	0.26		0.015	0.07	0.0034	0.28
(19)	〃	0.36	0.531	0.87	0.065	0.0030	0.018	0.0088	0.27	0.05	0.008	0.14	0.0011	0.38
20	比 較 例	0.07	0.480	1.12	0.026	0.0244	0.022	0.0149						0.3
21	〃	0.54	0.454	0.92	0.054	0.0313	0.012	0.0121						0.37
22	〃	0.39	0.003	1.09	0.046	0.0351	0.021	0.0119						0.38
23	〃	0.36	2.025	0.76	0.069	0.0215	0.016	0.0104						0.39
24	〃	0.23	0.316	0.37	0.038	0.0281	0.012	0.0098						0.31
25	〃	0.34	0.517	2.06	0.048	0.0316	0.015	0.0108						0.32
26	〃	0.23	0.601	0.68	0.008	0.0244	0.019	0.0132						0.54

単位：wt%

[0039]
[Table 2]

表1（その2）

No.		C	Si	Mn	S	Al	Ti	N	Cr	Mo	Nb	Pb	Ca	V
27	比 較 例	0.29	0.416	1.15	0.105	0.0335	0.02	0.0129						0.35
28	〃	0.29	0.290	0.70	0.038	0.0004	0.024	0.0097						0.49
29	〃	0.24	0.472	0.96	0.030	0.0514	0.023	0.0124						0.51
30	〃	0.26	0.524	0.61	0.024	0.0239	0.002	0.0132						0.52
31	〃	0.28	0.450	0.63	0.036	0.038	0.058	0.016						0.41
32	〃	0.20	0.456	0.73	0.040	0.0326	0.024	0.0018						0.34
33	〃	0.27	0.554	1.08	0.027	0.0333	0.014	0.0208						0.5
34	〃	0.36	0.418	1.05	0.066	0.0387	0.015	0.0096						0.18
35	〃	0.27	0.445	1.17	0.040	0.0204	0.011	0.0137						0.81
36	〃	0.34	0.537	1.05	0.055	0.0337	0.008	0.0094	1.52					0.37
37	〃	0.26	0.409	0.94	0.068	0.0311	0.011	0.0154		1.03				0.49
38	〃	0.21	0.451	0.76	0.021	0.0201	0.015	0.0141			0.221			0.45
39	〃	0.31	0.616	0.7	0.046	0.0239	0.009	0.0125				0.35		0.32
40	〃	0.26	0.522	0.64	0.048	0.0356	0.022	0.0151					0.0109	0.49
41	比較例：現行調質鋼	0.45	0.234	0.78	0.027	0.0282	--	0.0083	-	-	--	-	--	-

単位：wt%

[0040] The pearlite ratio of organized labor and performance-evaluation result of each test specimen are shown in Table 2.

[0041] First, all, No..[which is an example of this invention to the durable ratio 0.48 of 41 and cutting ability 1.00 / No] (1) - (19) which is the present heat treated steel mentioned as an example of a comparison is 0.56 or more, and a durable ratio is [its cutting ability] about 4 times from 2.7 times No.41. Moreover, the yield ratio of the example of this invention is 0.73 or more, the level near the yield ratio 0.8 of No.41 which are the present heat treated steel is obtained, and 20-degree-C impact resistance value of the example of this invention is also further acquired for the level more than the present heat treated steel and an EQC.

[0042] Since No.20 of the example of a comparison have the low amount of C, its tensile strength is low and yield strength and its fatigue strength are also low. Although bainite is generated, and the conditions of the ferrite + pearlite ratio of organized labor of this invention cannot be satisfied but tensile strength becomes high since No.21 of the example of a comparison have the too high amount of C, compared with the example of this invention, a yield ratio, toughness, and the durable ratio of cutting ability are low poor.

[0043] Since No.22 of the example of a comparison have the low amount of Si, deoxidation extent is low, and a durable ratio is low compared with the example of this invention. Since

No.23 of the example of a comparison have the high amount of Si, bainite is generated, the conditions of the ferrite + pearlite ratio of organized labor of this invention cannot be satisfied, but the cutting ability of a yield ratio, toughness, and a durable ratio is also low poor compared with the example of this invention.

[0044] Since No.24 of the example of a comparison have the low amount of Mn, there are few deposits of a compound sludge, and its a durable ratio is low compared with the example of this invention. Since No.25 of the example of a comparison have the high amount of Mn, bainite is generated, the conditions of the ferrite + pearlite ratio of organized labor of this invention cannot be satisfied, but the cutting ability of a yield ratio, toughness, and a durable ratio is also low poor compared with the example of this invention.

[0045] Since No.26 of the example of a comparison have the low amount of S, there are few deposits of a compound sludge, toughness and a durable ratio are low compared with the example of this invention, and since the improvement effectiveness in cutting ability of MnS is not acquired, cutting ability is also poor. Since the amount of S is high, the deposit of MnS becomes excessive, and No.27 of the example of a comparison have toughness and a low durable ratio compared with the example of this invention.

[0046] Since No.28 of the example of a comparison have few amounts of aluminum, deoxidation extent and its grain-refining effectiveness are small, and its a durable ratio is low compared with the example of this invention. Since No.29 of the example of a comparison have the high amount of aluminum, hard inclusion is formed, and compared with the example of this invention, the cutting ability of toughness and a durable ratio is also low poor.

[0047] Since No.30 of the example of a comparison have the low amount of Ti, there are few deposits of a compound sludge, and toughness and its a durable ratio are low compared with the example of this invention. Since No.31 of the example of a comparison have the high amount of Ti, hard inclusion is formed, and compared with the example of this invention, the cutting ability of toughness and a durable ratio is also low poor.

[0048] Since No.32 of the example of a comparison have the low amount of N, there are few deposits of a compound sludge, and its a durable ratio is low compared with the example of this invention. Since No.33 of the example of a comparison have the high amount of N, a matrix hardens, and compared with the example of this invention, the cutting ability of toughness and a durable ratio is also low poor.

[0049] Since No.34 of the example of a comparison have the low amount of V and the effectiveness which strengthens a matrix ferrite by precipitation hardening is [there are few deposits of a compound sludge and] small, a yield ratio and a durable ratio are low compared with the example of this invention. Since No.35 of the example of a comparison have the high amount of V, toughness of cutting ability is [35] low poor compared with the example of this invention.

[0050] Since No.36 of the example of a comparison have the high amount of Cr(s), bainite is generated, the conditions of the ferrite + pearlite ratio of organized labor of this invention cannot

be satisfied, but the cutting ability of a yield ratio, toughness, and a durable ratio is also low poor compared with the example of this invention.

[0051] Since No.37 of the example of a comparison have the high amount of Mo, bainite is generated, the conditions of the ferrite + pearlite ratio of organized labor of this invention cannot be satisfied, but the cutting ability of a yield ratio, toughness, and a durable ratio is also low poor compared with the example of this invention.

[0052] Since No.38 of the example of a comparison have the high amount of Nb(s), compared with the example of this invention, the cutting ability of toughness and a durable ratio is also low poor.

[0053] Although cutting ability is good since No.39 of the example of a comparison have the high amount of Pb(s), toughness and a durable ratio are low.

[0054] Although cutting ability is good since No.40 of the example of a comparison have the high amount of calcium, toughness and a durable ratio are low.

[0055]
[Table 3]

表2（その1）

No.		フェライト+パーライト 組織率		機械的性質						
		本発明範囲	実績値	引張強度 kgf/mm²	降伏強度 kgf/mm²	降伏比 －	20℃衝撃値 kgf-m/cm²	疲労強度 kgf/mm²	耐久比 －	切削性 －
(1)	第1発明例	≧0.90	0.95	88.7	65.6	0.74	4.2	51.4	0.58	2.81
(2)	〃	〃	0.96	89.1	67.7	0.76	4.8	50.8	0.57	3.02
(3)	〃	〃	0.94	87.3	65.5	0.75	5.7	50.6	0.58	2.56
(4)	〃	〃	0.98	87.4	65.6	0.75	5.2	50.7	0.58	3.02
(5)	〃	〃	0.98	85.4	63.2	0.74	6.2	49.5	0.58	2.68
(6)	第2発明例	〃	0.97	89.9	68.3	0.76	4.2	51.2	0.57	3.21
(7)	〃	〃	0.98	88.5	65.5	0.74	4.0	51.3	0.58	3.29
(8)	〃	〃	0.95	86.7	63.3	0.73	6.0	50.3	0.58	3.02
(9)	第3発明例	〃	0.95	84.7	63.5	0.75	6.5	49.1	0.58	3.13
(10)	〃	〃	0.98	84.3	63.2	0.75	6.5	48.9	0.58	2.85
(11)	〃	〃	0.94	85.1	64.7	0.76	6.0	50.2	0.59	3.17
(12)	第4発明例	〃	0.94	88.5	66.4	0.75	4.2	50.4	0.57	3.24
(13)	〃	〃	0.96	85.4	64.9	0.76	5.6	49.5	0.58	3.37
(14)	〃	〃	0.95	87.1	67.1	0.77	4.0	49.6	0.57	3.46
(15)	〃	〃	0.94	89.0	66.8	0.75	3.7	50.7	0.57	3.17
(16)	〃	〃	0.93	87.2	65.4	0.75	4.5	50.6	0.58	3.70
(17)	〃	〃	0.98	88.4	66.3	0.75	5.7	50.4	0.57	3.20
(18)	〃	〃	0.96	87.8	65.0	0.74	5.3	50.0	0.57	3.93
(19)	〃	〃	0.97	89.3	67.0	0.75	4.2	50.0	0.56	3.87
20	比較例	〃	0.98	68.4	47.9	0.70	11.0	35.6	0.52	3.16
21	〃	〃	0.56	98.4	63.0	0.64	1.8	41.3	0.42	0.62
22	〃	〃	0.96	87.6	57.8	0.66	2.0	42.9	0.49	1.82
23	〃	〃	0.76	103.6	63.2	0.61	1.0	53.9	0.52	0.74
24	〃	〃	0.97	66.8	47.4	0.71	12.0	32.1	0.48	3.54

[0056]
[Table 4]

表2（その2）

No.		フェライト+パーライト 組織率		機械的性質						切削性
		本発明範囲	実績値	引張強度 kgf/mm²	降伏強度 kgf/mm²	降伏比 －	20℃衝撃値 kgf-m/cm²	疲労強度 kgf/mm²	耐久比 －	－
25	〃	〃	0.66	100.1	61.1	0.61	1.0	43.0	0.43	0.53
26	〃	〃	0.96	89.8	64.7	0.72	2.4	45.8	0.51	0.81
27	〃	〃	0.97	86.1	60.3	0.70	1.2	33.6	0.39	3.12
28	〃	〃	0.94	87.6	63.9	0.73	3.0	38.5	0.44	0.97
29	〃	〃	0.97	90.8	63.6	0.70	1.6	45.4	0.50	0.44
30	〃	〃	0.97	89.0	64.1	0.72	2.6	39.2	0.44	1.24
31	〃	〃	0.96	82.3	55.1	0.67	3.2	39.5	0.48	0.68
32	〃	〃	0.96	73.2	49.8	0.68	7.2	32.9	0.45	1.10
33	比較例	≧0.90	0.97	95.0	68.4	0.72	1.0	45.6	0.48	0.95
34	〃	〃	0.98	77.8	52.1	0.67	6.8	35.8	0.46	2.68
35	〃	〃	0.72	115.3	84.5	0.73	0.5	51.0	0.44	0.42
36	〃	〃	0.46	103.3	69.2	0.67	1.4	44.4	0.43	0.54
37	〃	〃	0.41	114.0	74.1	0.65	1.0	45.6	0.40	0.43
38	〃	〃	0.95	81.3	57.7	0.71	2.8	34.1	0.42	0.44
39	〃	〃	0.97	81.4	57.0	0.70	3.0	30.9	0.38	3.82
40	〃	〃	0.95	86.7	61.6	0.71	2.0	32.9	0.38	3.54
41	〃	(QT組織)	0.0	83.2	66.6	0.80	4.5	39.9	0.48	1.00

[0057] b. The steel of the chemical entity shown in No. (14) of the effect table 1 of forging finishing temperature was dissolved with the high-frequency furnace, sub-hot forging was performed on condition that the finishing temperature which heated at 1050 degrees C and was shown in Table 3 once having considered as the 150kg steel ingot, having, started the charge of forging material from now on and carrying out normalizing by 950-degree-C heating radiationnal cooling, and it cooled radiationally after that. Furthermore this ingredient was inserted in the heating furnace with a temperature of 400 degrees C for 1 hour, and aging treatment was performed. By the approach same about these ingredients as Example a, a tension test, a Charpy impact test (20 degrees C), a fatigue test, cutting trial, and metal texture observation were performed. In addition, although 700 degrees C [of finishing temperature] sub-hot forging was tried, the forging load increased notably and was not able to cast. The performance-evaluation result of each test specimen is shown in Table 4.

[0058] No. -- No. whose cutting ability 42 and 43 have satisfied 750-900 degrees C which is the forging finishing temperature of this invention, and a durable ratio secures 0.57 or more for all, and is also the present heat treated steel -- it is as good as about 3.5 or more times of 45.

Moreover, the yield ratio of the example of this invention is 0.76 or more, the level near the yield ratio 0.8 of No.45 which are the present heat treated steel is obtained, and level also with 20-degree-C impact resistance value of the example of this invention almost equivalent to the present heat treated steel is obtained further.
[0059] No.44 are the case where forging finishing temperature exceeds the range of this invention, and a yield ratio and toughness are inferior in them.

[0060]
[Table 5]

表 3

No.	供 試 鋼	鍛造仕上げ温度 ℃
(42)	表1のNo.(14)	800
(43)	〃	850
44	〃	950
45	表1のNo.41 比較鋼：現行調質材	875℃油焼入れした後 570℃水冷焼戻し

[0061]
[Table 6]

表 4

No.		フェライト+パーライト 組織率		機 械 的 性 質						切削性
		本発明範囲	実績値	引張強度 kgf/mm²	降伏強度 kgf/mm²	降伏比 −	20℃衝撃値 kgf-m/cm²	疲労強度 kgf/mm²	耐久比 −	
(42)	本発明例	≧0.90	0.98	86.0	65.4	0.76	5.0	49.0	0.57	3.75
(43)	〃	〃	0.95	87.1	67.1	0.77	4.0	49.6	0.57	3.46
44	比 較 例	〃	0.92	90.4	66.9	0.74	2.1	50.0	0.55	3.00
45	〃	(QT組織)	0.0	83.2	66.6	0.80	4.5	39.9	0.48	1.00

[0062] c. Once having dissolved the steel of the chemical entity shown in No. (14) of the effect table 1 of change of the metal texture by the cooling approach after hot forging with the high-frequency furnace, having considered as the 150kg steel ingot, having, started the charge of forging material from now on and carrying out normalizing by 950-degree-C heating radiationnal cooling, it heated at 1050 degrees C, sub-hot forging was performed on the conditions of 850 degrees C of finishing temperature, and it cooled by the approach similarly shown in Table 5 after that. Furthermore this ingredient was inserted in the heating furnace with a temperature of 400 degrees C for 1 hour, and aging treatment was performed. By the approach same about these ingredients as Example a, a tension test, a Charpy impact test (20 degrees C), a fatigue test, cutting trial, and metal texture observation were performed. The performance-evaluation result of each test specimen is shown in Table 6.

[0063] It is as good as 3.5 or more times of No.51 which are the present non-heat-treated steel which, as for No.46, and 47 and 48, the ferrite + pearlite ratio of organized labor had satisfied the conditions of 0.9 or more and this invention, and, as for the durable ratio, all secured 0.56 or more, and also mentioned cutting ability as an example of a comparison. Moreover, the yield ratio of the example of this invention is 0.73 or more, the level near the yield ratio 0.8 of No.51 which are the present heat treated steel is obtained, and 20-degree-C impact resistance value of the example of this invention is also further acquired for the level more than the present heat treated steel and an EQC.

[0064] Although it reaches No.49, 50 considers as the low-temperature transformation organization which is mainly concerned with bainite or martensite by raising a cooling rate and tensile strength becomes high, a yield ratio, toughness, and a durable ratio are very low, and cutting ability is also poor and the tool life of cutting ability is very small.

[0065]
[Table 7]

表 5

No.	供 試 鋼	鍛造後の冷却方法	800 ～500 ℃までの平均冷速
(46)	表1のNo.(14)	グラスウール断熱材中で徐冷	約 0.30 ℃／秒
(47)	〃	自然放冷	約 0.8 ℃／秒
(48)	〃	衝風冷却	約 1.4 ℃／秒
49	〃	水ミスト噴射による急冷	約 4.0 ℃／秒
50	〃	油焼入れ槽に投入、急冷	約 30 ℃／秒
51	表1のNo.41 比較鋼：現行調質材	８７５℃油焼入れした後 ５７０℃水冷焼戻し	－－－

[0066]
[Table 8]

表 6

No.		フェライト+パーライト 組織率		機械的性質						切削性
		本発明範囲	実績値	引張強度 kgf/mm²	降伏強度 kgf/mm²	降伏比 −	20℃衝撃値 kgf-m/cm²	疲労強度 kgf/mm²	耐久比 −	−
(46)	本発明例	≧0.90	0.98	87.4	63.8	0.73	5.2	48.9	0.56	4.10
(47)	〃	〃	0.95	87.1	67.1	0.77	4.0	49.6	0.57	3.46
(48)	〃	〃	0.92	89.2	66.9	0.75	4.0	50.0	0.56	3.54
49	比較例	〃	0.60	92.6	63.9	0.69	3.2	46.3	0.50	2.80
50	〃	〃	0.05	94.5	66.2	0.70	2.6	44.4	0.47	1.40
51	〃	(QT組織)	0.0	83.2	66.6	0.80	4.5	39.9	0.48	1.00

[0067] d. Once having dissolved the steel of the chemical entity shown in No. (14) of the effect table 1 of change of aging treatment temperature with the high-frequency furnace, having considered as the 150kg steel ingot, having, started the charge of forging material from now on and carrying out normalizing by 950-degree-C heating radiationnal cooling, it heated at 1050 degrees C, and on the conditions of 850 degrees C of finishing temperature, sub-hot forging was performed and it cooled after that. Aging treatment was performed on condition that the versatility which furthermore shows this ingredient in Table 7. By the approach same about these ingredients as Example a, a tension test, a Charpy impact test (20 degrees C), a fatigue test, cutting trial, and metal texture observation were performed. The performance-evaluation result of each test specimen is shown in Table 8.

[0068] No.53, and 54 and 55 have satisfied 200-700 degrees C which is the aging temperature requirement of this invention, and a durable ratio secures 0.56 or more for all, and it is as good as about 3.5 or more times of No.57 whose cutting ability is also the present heat treated steel. Moreover, the yield ratio of the example of this invention is 0.72 or more, the level near the yield ratio 0.8 of No.57 which are the present heat treated steel is obtained, and level also with 20-degree-C impact resistance value of the example of this invention almost equivalent to the present heat treated steel is obtained further.

[0069] No.52 are the case where aging temperature is less than the range of this invention, and are inferior in a yield ratio and a durable ratio. Moreover, No.56 are the case where aging temperature exceeds the range of this invention, and are inferior in a yield ratio and a durable ratio too.

[0070]
[Table 9]

表 7

No.	供 試 鋼	テ ン パ ー 条 件
52	表1のNo.(14)	１００℃×１時間→水冷
(53)	〃	３００℃×１時間→空冷
(54)	〃	４００℃×１時間→水冷
(55)	〃	６００℃×１５分→水冷
56	〃	７２０℃×３０分→水冷
57	表１のNo.41 比較鋼：現行調質材	８７５℃油焼入れした後 ５７０℃水冷焼戻し

[0071]
[Table 10]

表 8

No.		フェライト+パーライト 組織率		機 械 的 性 質						切削性 −
		本発明範囲	実績値	引張強度 kgf/mm²	降伏強度 kgf/mm²	降伏比 −	20℃衝撃値 kgf-m/cm²	疲労強度 kgf/mm²	耐久比 −	
52	比 較 例	≧0.90	0.96	92.2	59.0	0.64	3.0	47.9	0.52	3.64
(53)	本発明例	〃	0.97	91.3	65.7	0.72	3.5	51.1	0.56	3.85
(54)	〃	〃	0.95	87.1	67.1	0.77	4.0	49.6	0.57	3.46
(55)	〃	〃	0.97	86.5	65.7	0.76	4.6	48.4	0.56	4.15
56	比 較 例	〃	0.96	83.4	56.7	0.68	4.2	42.5	0.51	4.20
57	〃	(QT組織)	0.0	83.2	66.6	0.80	4.5	39.9	0.48	1.00

[0072]
[Effect of the Invention] As stated above, after securing cutting ability and adjusting C and the amount of V by considering this invention approach as a ferrite-pearlite 2 phase organization Perform sub-hot forging on the conditions whose forging finishing temperature is 750-900 degrees C, using the compound sludge formed from MnS, Ti nitride, and V nitride, and a metal texture is made detailed. The ferrite matrix in the pearlite by V carbide (or carbon nitride) is strengthened by performing aging treatment. A durable ratio, i.e., a fatigue property, is raised without this spoiling cutting ability. Effectiveness is very large on the industry which becomes possible [also raising a yield ratio and toughness], and offers the manufacture approach of sub-hot forged microalloyed steel of being satisfied with coincidence of improvement in the fatigue property for which it was anxious from the former, cutting ability, a breakdown property, and toughness.

[Translation done.]